

CLAIMS

1. A high-strength hot-dip galvanized steel sheet characterized by:

containing, in weight,

- 5 C: 0.03 to 0.25%,
Si: 0.05 to 2.0%,
Mn: 0.5 to 2.5%,
P: 0.03% or less,
S: 0.02% or less, and
10 Al: 0.01 to 2.0%,

with the relationship among Si, Mn and Al satisfying the following expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

a hot-dip plating layer being formed on
15 each of the surfaces of said steel sheet; and
5 to 80 % of the surface area of said steel sheet being
occupied by oxides when said steel sheet surface is
observed with a scanning electron microscope after a hot-
dip plating layer is dissolved by fuming nitric acid.

20 2. A high-strength hot-dip galvanized steel sheet according to claim 1, characterized by further containing, in weight, one or both of

Ni: 0.01 to 2.0% and
Cr: 0.01 to 0.5%.

25 3. A high-strength hot-dip galvanized steel sheet according to claim 1 or 2, characterized by the oxides on said steel sheet surface containing one or more of Si, Mn and Al.

30 4. A high-strength hot-dip galvanized steel sheet according to claim 2, characterized by further containing, in weight, one or more of

Mo: 0.01 to 0.5%,
Cu: 0.01 to 1.0%,
Sn: 0.01 to 0.10%,
35 V: less than 0.3%,
Ti: less than 0.06%,
Nb: less than 0.06%,

B: less than 0.01%,
REM: less than 0.05%,
Ca: less than 0.05%,
Zr: less than 0.05%, and
Mg: less than 0.05%.

5 5. A high-strength hot-dip galvanized steel sheet characterized by, when said steel sheet contains retained austenite and only Mo is added among the elements stipulated in claim 4:

10 the relationship among Si, Al and Ni satisfying the following expressions,

$0.4 (\%) \leq \text{Si} (\%) + \text{Al} (\%) \leq 2.0 (\%),$
 $\text{Ni} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%),$ and
 $1/20 \times \text{Ni} (\%) \leq \text{Mo} (\%) \leq 10 \times \text{Ni} (\%);$ and

15 the volume ratio of said retained austenite in said steel sheet being in the range from 2 to 20%.

6. A high-strength hot-dip galvanized steel sheet characterized by, when said steel sheet contains retained austenite and Cu or Sn is further added in addition to Mo among the elements stipulated in claim 4:

20 the relationship among Ni, Cu and Sn satisfying the following expression,

$2 \times \text{Ni} (\%) > \text{Cu} (\%) + 3 \times \text{Sn} (\%);$

25 the relationship among Si, Al, Ni, Cu and Sn satisfying the following expression,

$\text{Ni} (\%) + \text{Cu} (\%) + 3 \times \text{Sn} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%);$ and

30 the volume ratio of said retained austenite in said steel sheet being in the range from 2 to 20%.

35 7. A method for producing a high-strength hot-dip galvanized steel sheet characterized in that the volume ratio of retained austenite in said steel sheet is in the range from 2 to 20% and a hot-dip galvanizing layer is formed on each of the surfaces of said steel sheet by

subjecting a steel sheet satisfying the component ranges stipulated in claim 5 or 6 to the processes of: annealing the hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in the dual phase coexisting temperature range of 750°C to 900°C; subsequently cooling up to 350°C to 500°C at a cooling rate of 2 to 200°C/sec., or occasionally heat retention for 10 min. or less in said temperature range; subsequently hot-dip galvanizing; and thereafter cooling to 250°C or lower at a cooling rate of 5°C/sec. or more.

8. A method for producing a high-strength hot-dip galvanized steel sheet characterized in that the volume ratio of retained austenite in said steel sheet is in the range from 2 to 20% and an alloyed hot-dip galvanizing layer containing 8 to 15% Fe is formed on each of the surfaces of said steel sheet by subjecting a steel sheet satisfying the component ranges stipulated in claim 5 or 6 to the processes of: annealing the hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in the dual phase coexisting temperature range of 750°C to 900°C; subsequently cooling up to 350°C to 500°C at a cooling rate of 2 to 200°C/sec., or occasionally heat retention for 10 min. or less in said temperature range; thereafter hot-dip galvanizing; subsequently heat retention for 5 sec. to 2 min. in the temperature range from 450°C to 600°C; and thereafter cooling to 250°C or lower at a cooling rate of 5°C/sec. or more.

9. A method for producing a high-strength hot-dip galvanized steel sheet characterized by subjecting a steel sheet satisfying the component ranges stipulated in claim 1 or 2, before subjecting said steel sheet to hot-dip galvanizing, to treatment in an atmosphere controlled so that: said atmosphere may have an oxygen concentration of 50 ppm or less in the temperature range from 400°C to 750°C; and, when a hydrogen concentration, a dew point and an oxygen concentration in said atmosphere are defined by H (%), D (°C) and O (ppm) respectively, H, D

and O may satisfy the following expressions for 30 sec. or longer in the temperature range of 750°C or higher,

O (30 ppm, and

$$20 \times \exp(0.1 \times D) \leq H \leq 2,000 \times \exp(0.1 \times D).$$

5 10. A method for producing a high-strength hot-dip galvanized steel sheet characterized by subjecting a steel sheet satisfying the component ranges stipulated in claim 2, before subjecting said steel sheet to hot-dip galvanizing, to treatment in an atmosphere controlled so
10 that, when a hydrogen concentration and a dew point in said atmosphere and an Ni concentration in said steel sheet are defined by H (%), D (°C) and Ni (%) respectively, H, D and Ni may satisfy the following expression for 30 sec. or longer in the temperature range
15 of 750°C or higher,

$$3 \times \exp\{0.1 \times (D + 20 \times (1 - \text{Ni} (\%)))\} \leq H \leq 2,000 \times \exp\{0.1 \times (D + 20 \times (1 - \text{Ni} (\%)))\}.$$

 11. A high-strength hot-dip galvanized steel sheet according to claim 1, a hot-dip galvanizing layer being
20 formed on each of the surfaces of said steel sheet, characterized in that, when a section of said steel sheet is observed with an SEM, wherein the surface of the steel sheet immediately under said hot-dip galvanizing layer is oxidized.

25 12. A high-strength hot-dip galvanized steel sheet according to claim 1 or 2, characterized in that said steel sheet is further heated and alloyed.

 13. A high-strength hot-dip galvanized steel sheet according to claim 1, a hot-dip galvanizing layer being
30 formed on each of the surfaces of said steel sheet, characterized in that, when a section of said steel sheet is observed with an SEM, the maximum length of oxides observed in the surface layer of the base material immediately under said hot-dip galvanizing layer is 3 μm
35 or less and said oxides have gaps between them.